Avoiding Pitfalls in the Development of Phosphorus Removal Feasibility Studies and Discharge Optimization Plans

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Outline

1) Waste Characterization
   a. What? And Where?
   b. When?
   c. How?
   d. Why?
2) Jar Testing
3) Screening of Alternatives
4) Pilot Testing
5) Economic Evaluation

1. Waste Characterization

What?

Pitfall

Are assumptions being made based on limited data and rule of thumb ratios about 'quality' of substrate?

BOD5/TP

COD/TP

BOD5/NH3-N

BOD_5 and COD to Phosphorus Removal Ratios as Associated with Various Types of Biological Phosphorus Removal Processes

Types of BRP Process	$BOD_5/\Delta P$ Ratio (mg BOD5/mg-P)	COD/ΔP Ratio (mg COD/mg-P)
High efficiency (e.g., A/O without nitrification, VIP, UCT)	15-20	26-34
Moderate efficiency (e.g., A/O and A20 with nitrification)	20-25	34-43
Low efficiency (e.g., Bardenpho)	>25	>43

Grady, C., P.Leslie et al. 2011. Biological Wastewater Treatment. Boca Raton, FL: CRC Press.

1. Waste Characterization

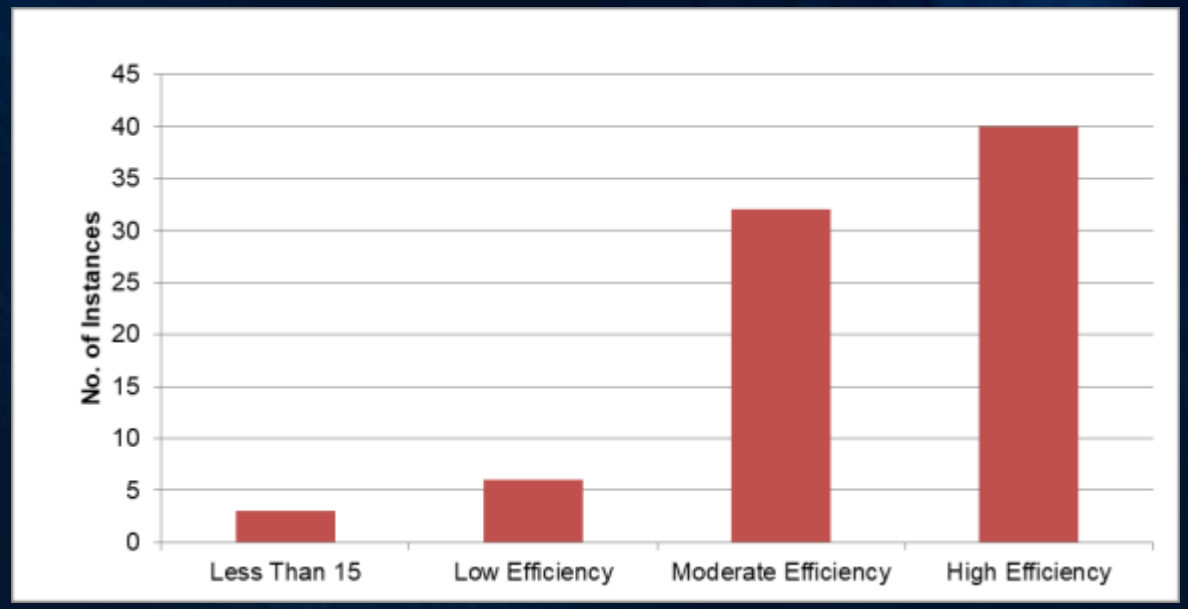
What?

Example of BOD5/TP Histogram and Probability Distribution

Pitfall

Are outliers being identified – and how?

Sanity Check



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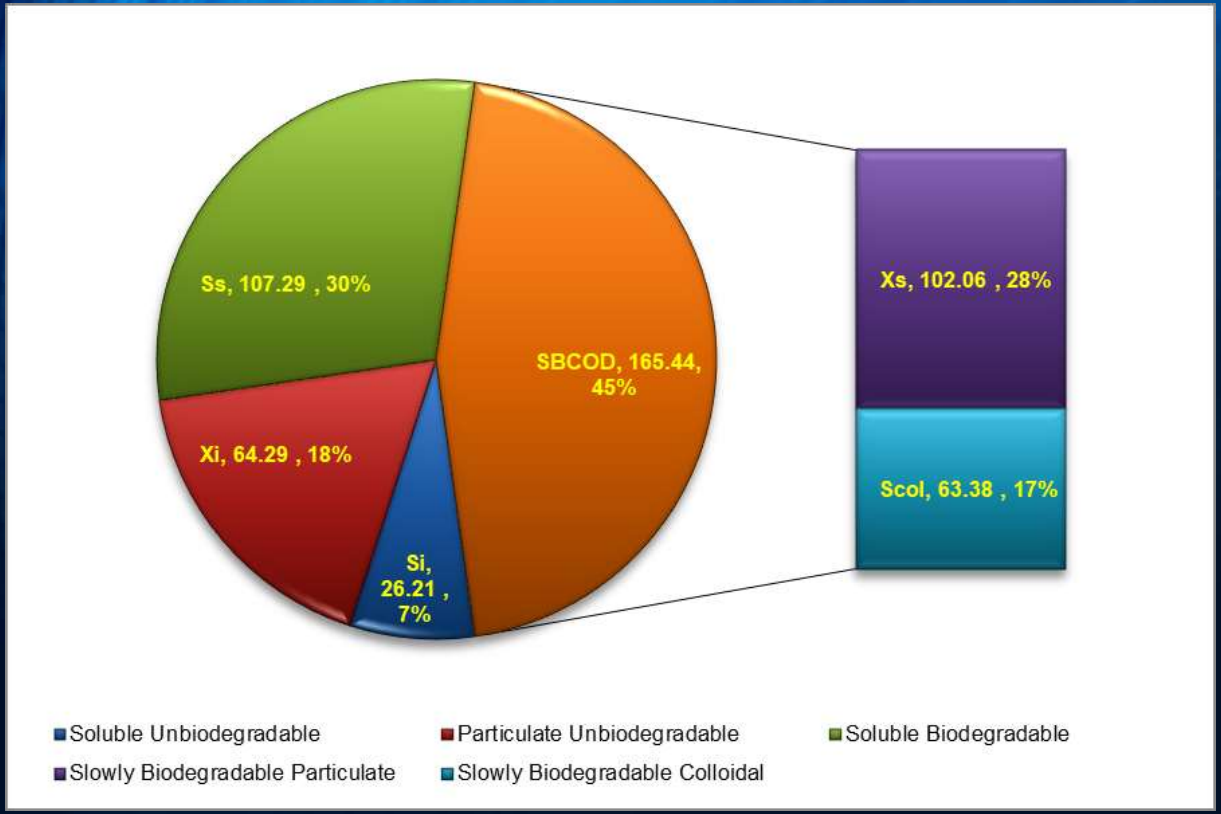
1. Waste Characterization

What?

A better approach is to speciate the important parameters to better understand the 'quality' of substrate.

- COD
- TP
- TKN

Example of PCE Speciation from data collected during Pilot Study



1. Waste Characterization

What and Where?

- **Influent**
- **PCE**
- **FCE**
- **Effluent**
- **Filtrate, Centrate**

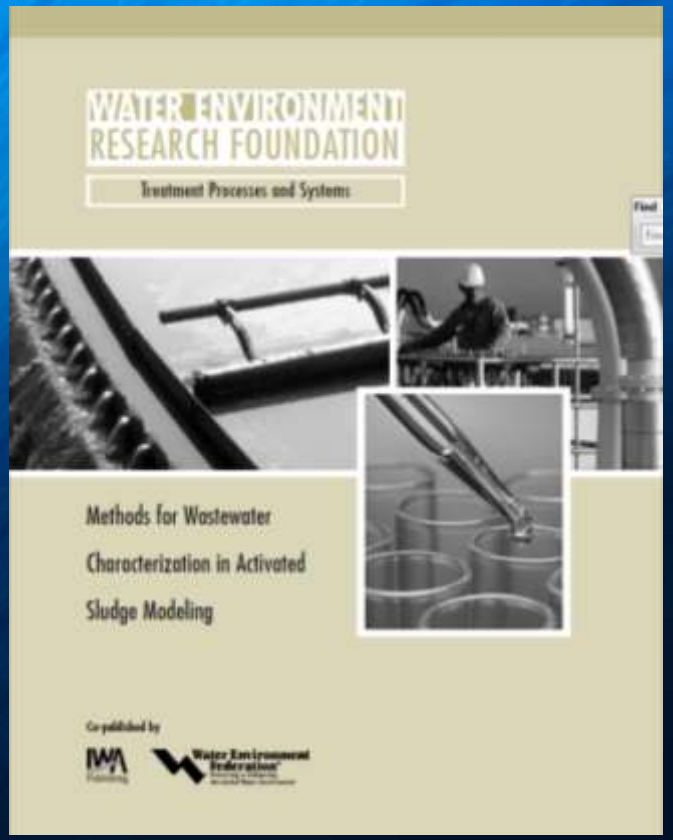
Pitfall

Temporal Concerns: Are there variations between collected data and instrumentation?

1. Waste Characterization

What and Where?

WASTEWATER CHARACTERIZATION	
PARAMETER	COMMENTS
RAW INFLUENT:	
Flow (average daily)	
TSS	
VSS	For calculation of ISS
COD (total)	
COD (GF filtrate)	For calculation of influent solids COD/VSS
ffCOD	For RBCOD
BOD_5 (total)	COD/BOD for estimating inert particulate COD
VFA	Analytical Procedure not the same as VFA in Digester
TKN (total)	
TKN (GF filtrate)	For calculation of influent solids N/VSS
Ammonia	
Nitrate	Spot checks - usually zero
TP	
Ortho-P (PO_4-P)	
Alkalinity	
pH	
Mg	
Ca	



1. Waste Characterization

What and Where?

ACTIVATED SLUDGE PROCESS:	
MLSS	Profile in step feed systems
MLVSS	
D.O.	Zone to zone, and variation over 24 hours
RAS flow	Details of flow-pacing
RAS TSS	
WAS flow	Details of intermittent wasting
WAS TSS*	May duplicate RAS TSS
Mixed Liquor recycle flow(s)	
Temperature	
SECONDARY EFFLUENT:	
TSS	
COD (total)	
ffCOD	For RBCOD
BOD_5 (0.45 µm filtrate)	
TKN (0.45 µm filtrate)	
Ammonia	
Nitrate	
Nitrite	Spot checks - should be zero
TP (0.45 µm filtrate)	
Ortho-P (PO_4-P)	
Alkalinity	
pH	

1. Waste Characterization

What and Where?

Thickening and BFP Underflows:	
Flow	Details of intermittent return
TSS	Sampling needs depend on stream type
VSS	
COD (tota, GF filtrate)	
ffCOD, VFA	For fermenter streams
BOD_5 (total)	
TKN, NH_3, NO_3	
TP, PO_4-P	
Alkalinity	
pH	

1. Waste Characterization

When?

Design Sampling Program to Address Temporal Concerns. This may require multiple sample periods or an extended sampling period.

Pitfall

Are Seasonal Variations Being Considered? And the impacts of varying flows: dry weather, wet weather, seasonal fluctuations, industrial loadings?

Pitfall

Temporal Concerns: Are there variations between collected data and instrumentation?

1. Waste Characterization

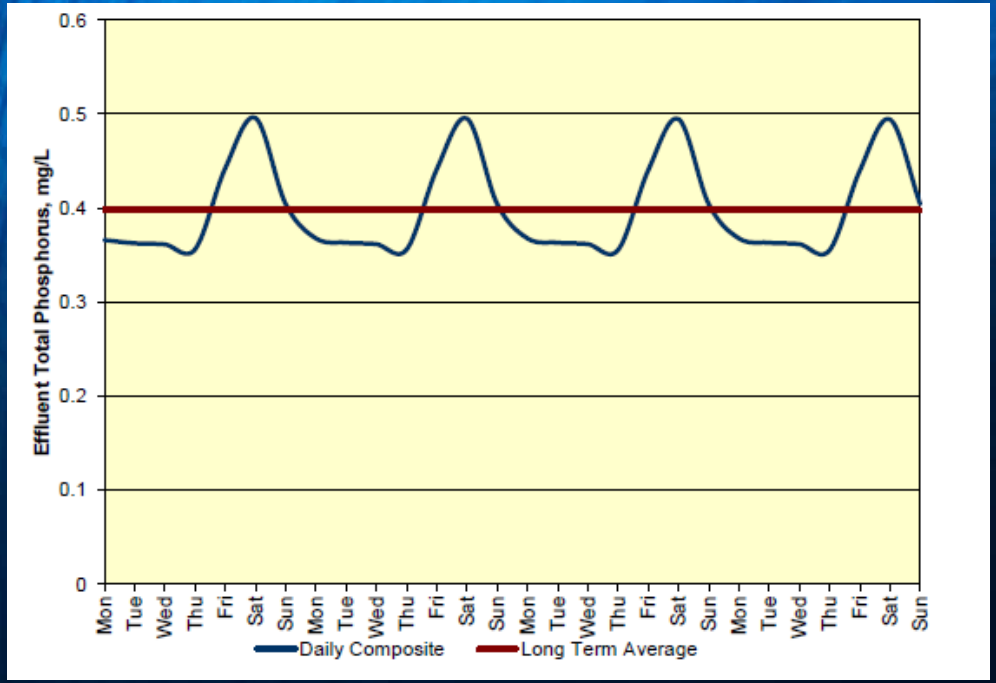
How?

- Composite
- Grab

1. Waste Characterization

Why?

- Garbage In = Garbage Out
- Investing Millions of Public Dollars
- Quest for Cost Effective Solutions



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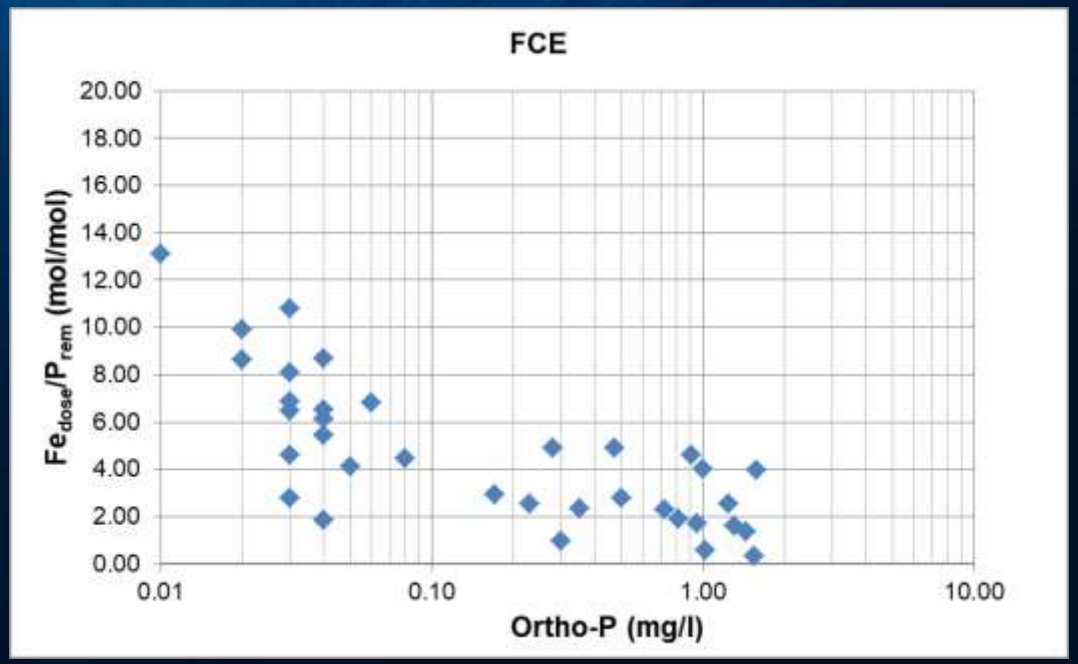
2. Jar Testing

- Jar Testing is a Must for Final Design
- Locations of Dosing
  - PCE
  - MLSS
  - FCE
  - Filtrate from Dewatering
- Alum or Ferric Chloride
  - For Plants with Anaerobic Digestion, Ferric May be a Better Choice

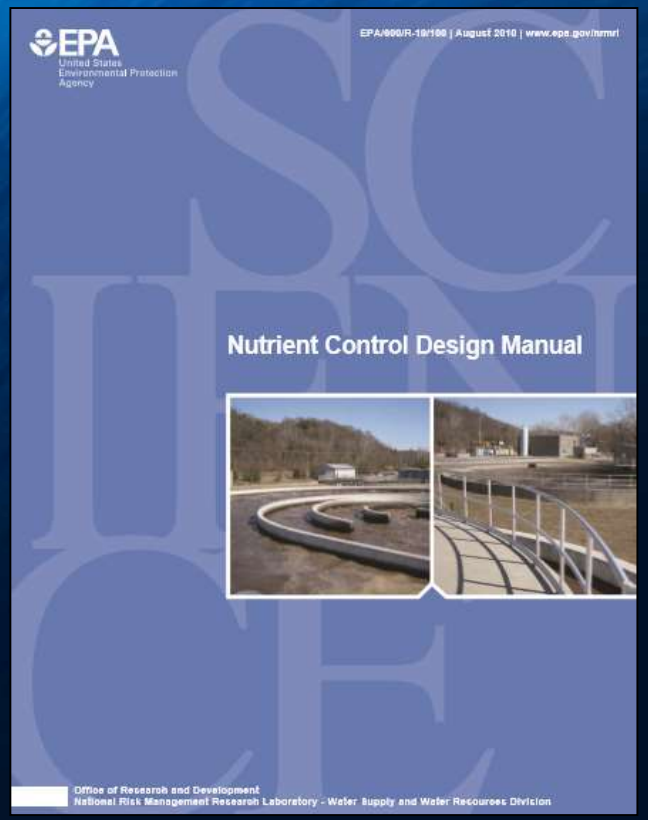


3. Screening of Alternatives

Results of Waste Characterization coupled with Modeling

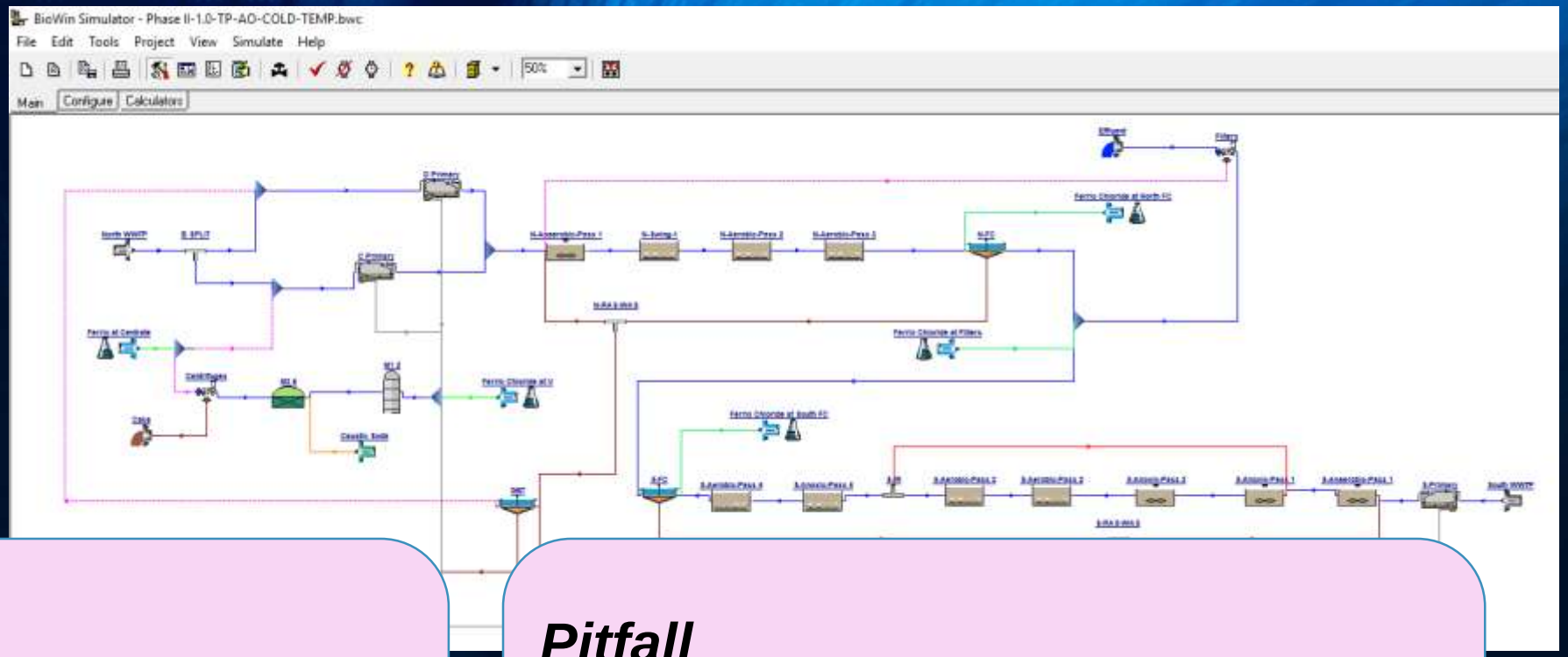
Benefits of Using Models for Process Design

The traditional approach for designing biological nutrient removal systems (e.g., for nitrification) was to determine solids residence time (SRT) based on kinetic equations, then to apply a safety factor based on engineering judgment. The new method currently being used by design engineers is to determine site specific nitrification kinetics based on influent quality and perform dynamic modeling of the system to capture variability. Lower safety factors can be used in design with more confidence that the plant can achieve the desired treatment objectives under a variety of operating conditions.



3. Screening of Alternatives

- Steady State
- Dynamic
- Identify KPI's
- Calibration
- Validation



Pitfall

Are recycle flows from batch processes properly accounted for…centrate…filtrate?

Pitfall

After model has been calibrated, has it been checked using an independent data set? Validation.

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Steady State Modeling of Existing Conditions - Calibration

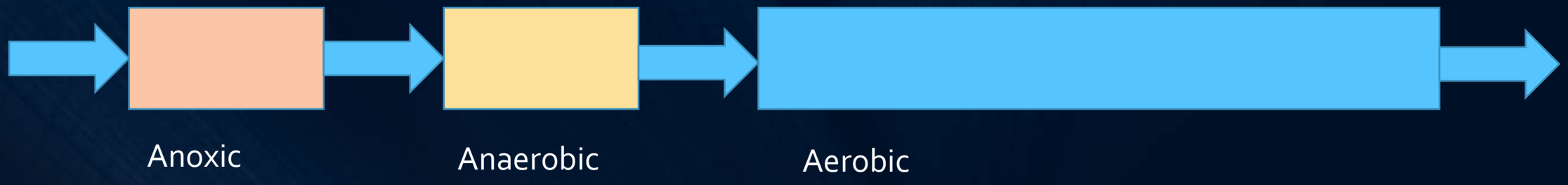
Key Process Indicators

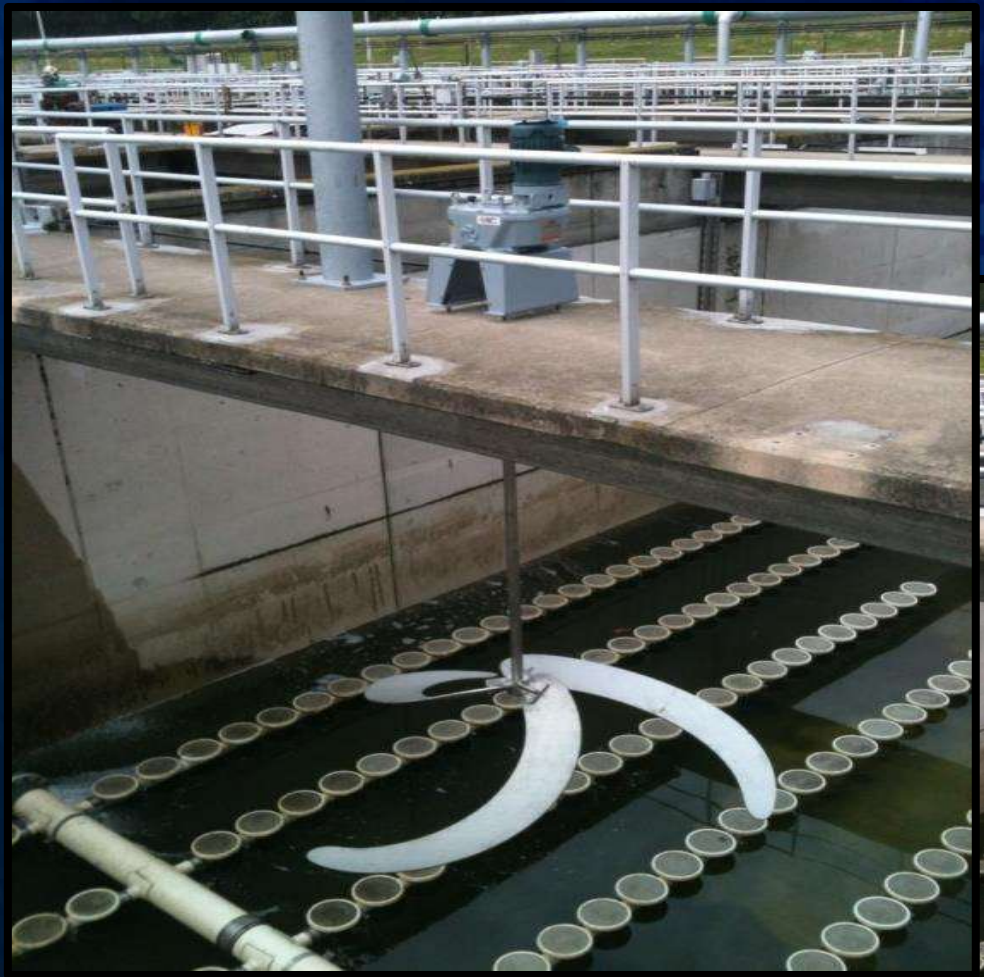
	10%	-1 std. dev.	Measured Median	+1 std. dev.	90%	Modeled	Variance
EFFLUENT							
cBOD	2.00	2.04	2.69	3.34	4.00	1.39	NA
COD	8.00	12.97	19.76	26.56	30.30	22.54	14%
TSS	1.00	1.42	2.88	4.34	5.40	2.98	-3%
TN	16.10	17.55	20.30	23.06	24.20	27.03	-33%
Ammonia-N	0.06	-	0.27	0.42	0.66	0.43	-64%
TP	1.91	1.91	2.71	3.52	3.65	3.29	-21%
SOLIDS							
C-PRIMARY SLUDGE	2.95	3.08	4.04	5.01	4.97	4.16	-3%
D-PRIMARY SLUDGE	2.33	2.53	4.02	5.51	5.96	4.40	-9%
GBT TWAS	3.99	4.04	5.13	6.22	6.28	5.27	-3%
CENTRIFUGE CAKE	20.55	20.95	23.15	25.35	24.90	23.00	1%
MLSS	2,810	2,763	3,295	3,827	4,042	3,163	4%
MLVSS	2,385	2,328	2,753	3,179	3,352	2,708	2%
RAS	6,311	6,368	7,804	9,241	9,790	7,855	-1%
GBT FILTRATE SOLIDS	1,000	1,036	1,208	1,380	1,400	1,282	-6%
CENTRATE SOLIDS	1,600	1,666	2,132	2,302	2,500	2,164	-2%

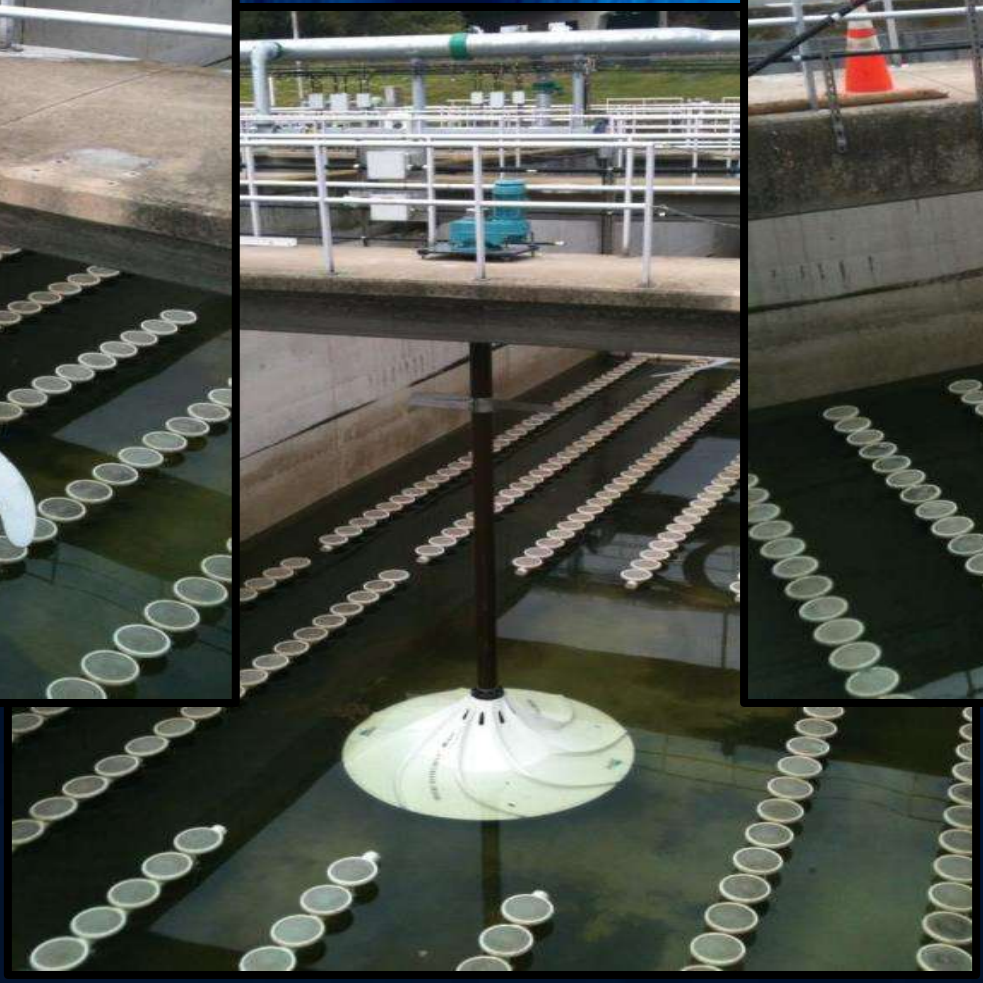
3. Biological Process Pilot Study - Example

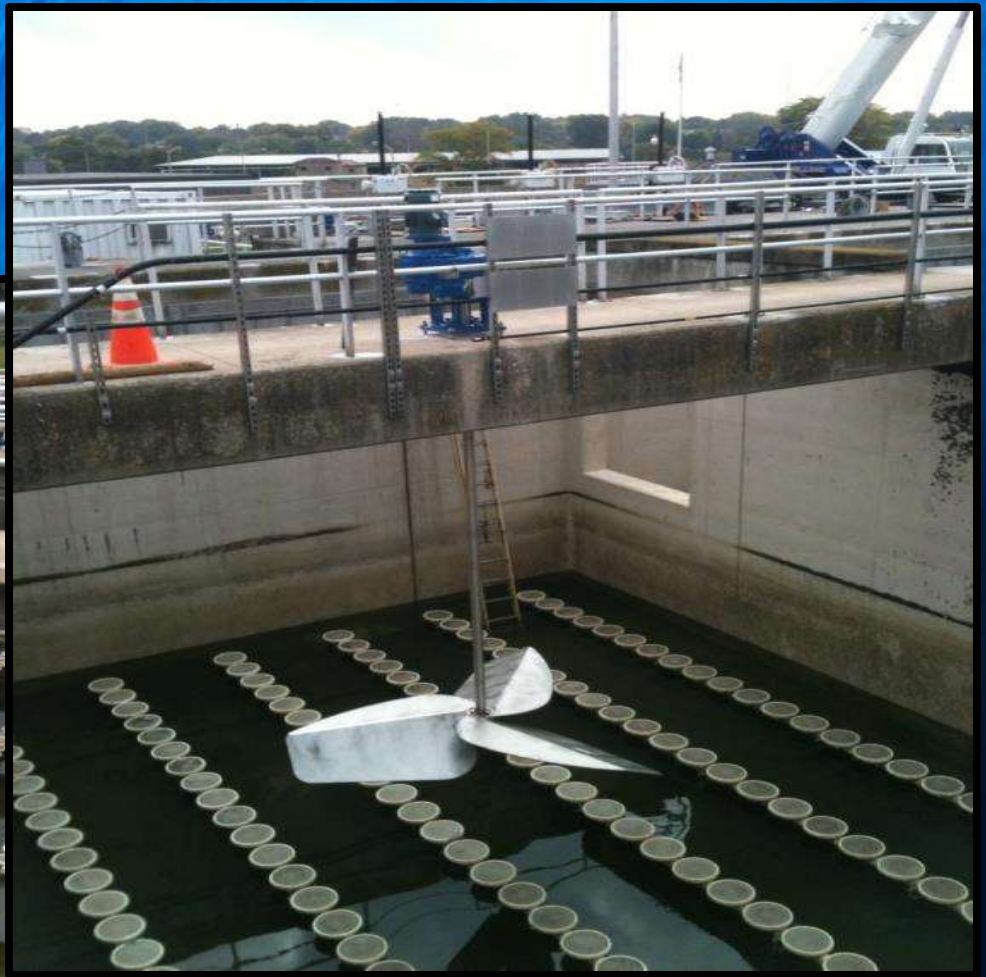
- Two parallel treatment trains
  - September 1 – October 31, 2015
- Train 1 – Single Stage Nitrification
- Train 2 – Bio P Process
  - Pass 1 operated as an anaerobic zone
  - ORP probe installed at beginning and mid pass and end of Pass 1

<u>Pitfall</u>
Can you pilot? Minimal Investment May Pay Dividends.









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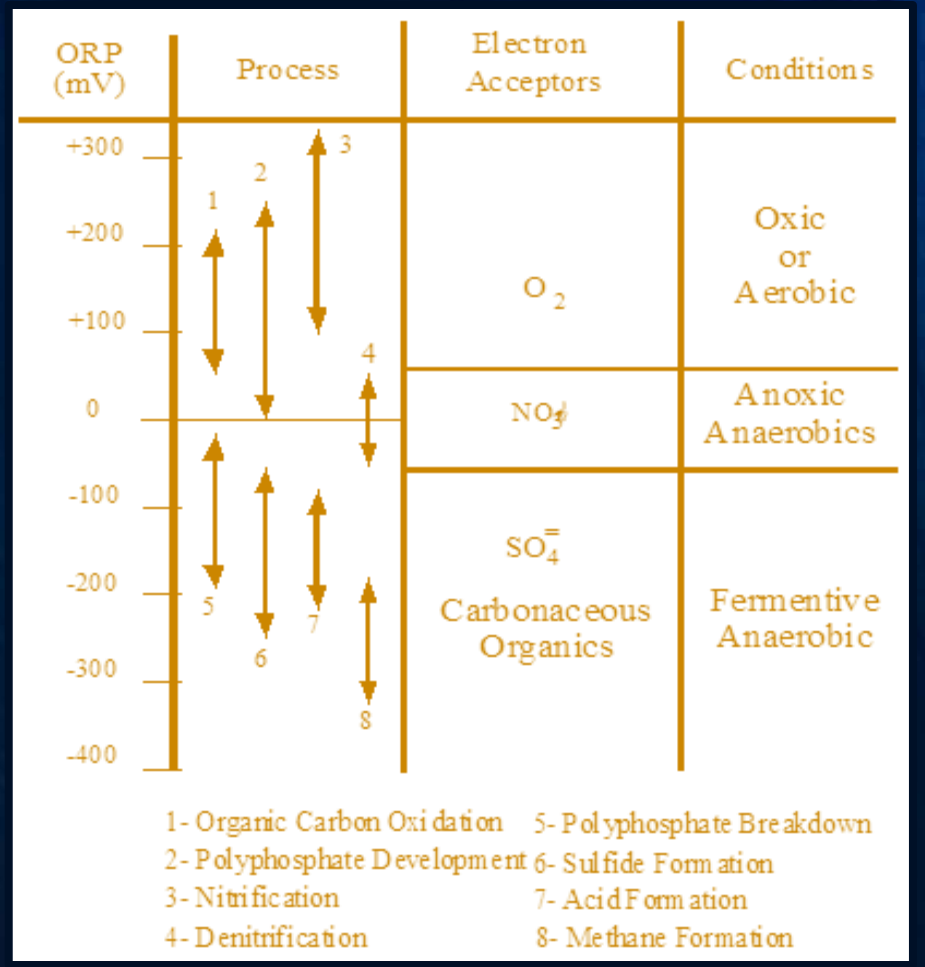
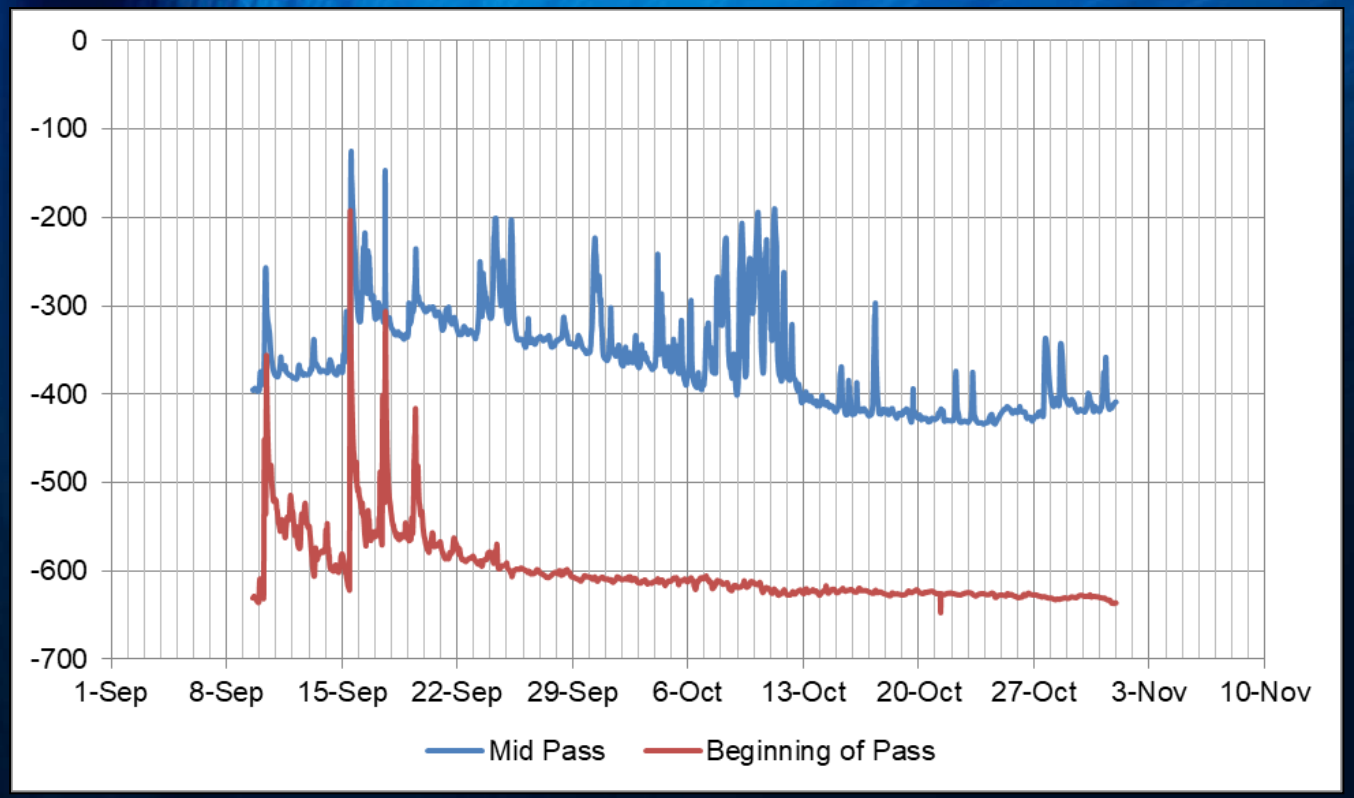
3. Biological Process Pilot Study - Example

Pilot Study Results					
Average Final Clarifier Effluent Concentrations, mg/l					
	Influent	Train 1		Train 2 - Pilot	
		Measured	Removed	Measured	Removed
Total P	6.36	2.50	3.86	0.80	5.56
Soluble P	4.16	2.03	2.13	0.56	3.60
Particulate P	2.20	0.47	1.73	0.24	1.96

- *Tetrasphaera* sp. in symbiosis with Accumulibacter at low ORPs
- 1.4 mg/l (441 lbs/d) additional SP removed with Bio-P process.
  - If chemical were used to remove 441 lbs/d of P, 2,022 gpd at 3:1 mole Fe: mole P. 20 yr PW of $10.7 million.
- Baffles need to prevent bleed back of air from Pass 2 to Pass 1

3. Biological Process Pilot Study - Example





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4. Economic Evaluation

- Present Worth Evaluation
- Capital Costs
- M & O Costs
  - Chemical
  - Power
  - Maintenance Manpower
  - Excess Sludge
  - Replacement Costs

Pitfall

Not taking into account inflation. For example, a $10 Million Project with $350,000 in Annual M&O. (5% interest, 3% Inflation, 20 years)

Has a PW of $15.5 M

$14.4 if inflation is ignored.

DISCUSSION AND